| NASA/GSFC | MISSION OPERATIONS & DATA SYSTEMS DIRECTORATE (MO&DSD)<br>CONFIGURATION CHANGE REQUEST (CCR) | | | |
|---|---|---|---|---|
| **1. CCR NO.**<br>8137 | CCR-405-SY011-02 | **2. DATE**<br>July 17, 1998 | **3. PRIORITY**<br>☐ EMERGENCY<br>☐ URGENT<br>■ ROUTINE | **4. CHANGE LEVEL**<br>☐ A ☐ B ☐ C<br>■ D ☐ E ☐ F |

**5. TITLE OF CHANGE**

Incorporation of ECPs 002A, 007, 011 and TDRS CCR 8087

**6.**

**DOCUMENT TITLE** White Sands Complex (WSC) Ground Terminal Requirements for the TDRS H,I,J Era

**DOCUMENT NO.** 405-TDRS-RP-SY-011, 8 December 1995

**LIST ALL AFFECTED DOCUMENTS INCLUDING PROCEDURES** 530-RSD-WSC, Rev. 1

(CONT ON ATTACHMENT)

**7. REASON FOR CHANGE**

To incorproate TDRS H,I,J Project contractor inputs for H,I,J Project/WSC compatibility

(CONT ON ATTACHMENT)

**8. DESCRIPTION OF CHANGE**

See attached

(CONT ON ATTACHMENT)

**9. IMPACT**

| YES | NO | | YES | NO | | YES | NO | | YES | NO | | YES | NO | | YES | NO | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ☐ | ■ | SCHEDULE | ☐ | ■ | RELIABILITY/MAINTAIN-ABILITY/SAFETY | ■ | ☐ | GROUND SEGMENT | ☐ | ■ | 501 | ■ | ☐ | 530 | ☐ | ■ | MSFC | ☐ | ■ | CODE E |
| ☐ | ■ | BUDGET | ☐ | ■ | | ☐ | ■ | SPACE SEGMENT | ☐ | ■ | 502 | ☐ | ■ | 540 | ☐ | ■ | JSC | ☐ | ■ | CODE S |
| ☐ | ■ | FACILITIES | ☐ | ■ | USER SERVICES/MANUALS | ☐ | ■ | LOGISTICS | ☐ | ■ | 503 | ☐ | ■ | 550 | ☐ | ■ | LERC | ☐ | ■ | CODE T |
| ☐ | ■ | TESTING | ☐ | ■ | RISK MANAGEMENT | ■ | ☐ | DOCUMENTATION | ☐ | ■ | 510 | ☐ | ■ | 560 | ☐ | ■ | KSC | ☐ | ■ | OTHER |
| ☐ | ■ | TRAINING | ☐ | ■ | SECURITY | ☐ | ■ | HARDWARE | ☐ | ■ | 520 | ■ | ☐ | OTHER | ☐ | ■ | JPL | | | |
| ■ | ☐ | SPECIFICATIONS | ☐ | ■ | USAF FUNDING REQ'D | ☐ | ■ | SOFTWARE | | | | Code 405 | | | | | | | | |
| ☐ | ■ | CONTRACTOR SUPPORT | ☐ | ■ | POWER | ☐ | ■ | OTHER | | | | | | | | | | | | |
| ☐ | ■ | INTERFACES | ☐ | ■ | WEIGHT | | | | | | | | | | | | | | | |

**10. COMMENTS**

| | SIGNATURE | DATE |
|---|---|---|
| STel ANALYST | | |
| HARDWARE ENGINEER | | |
| OPERATIONS REPRESENTATIVE | | |
| SYSTEMS ENGINEER | | |
| I AND T MANAGER | | |

**CONCURRENCE:**

CODE 285

DATE

**11. BOARD ACTION**

☐ APPROVED ☐ WITHDRAWN
☐ DISAPPROVED ☐ DEFERRED UNTIL _____

**12. DIRECTION/ACTION REQUIRED**

☐ ECP ☐ TECH DIRECTION ☐ CONTRACT MOD
☐ WAIVER ☐ PUBLISH DOCUMENT ☐ PUBLISH DCN
☐ DEVIATION ☐ C.O. LETTER ☐ OTHER _____

**13. ORIGINATOR** D. Littmann x7643 **CODE** 451

SIGNATURE _____ DATE _____

**14. SEGMENT MANAGER'S APPROVAL** CODE _____

SIGNATURE _____ DATE _____

**15. CCB APPROVAL**

SIGNATURE _____ DATE _____

**16. CCR IMPLEMENTED**

ATR SIGNATURE _____ DATE _____

CCB SIGNATURE _____ DATE _____

# Change Information Page

| List of Effective Pages | |
|---|---|
| **Page Number** | **Issue** |
| B-1 through B-67/B-68 | Original |
| Appendix C | Deleted |
| Appendix D | Separate Volume |
| E-1 through E-22 | Original |
| F-1 through F-3/F-4 | Original |
| G-1 through G-3/G-4 | Original |
| H-1 through H-5/H-6 | Original |
| I-1 through I-26 | Original |
| J-1 through J-5/J-6 | Original |
| K-1 through K-42 | Original |
| L-1 through L-13/L-14 | Original |
| M-1 through M-12 | Original |
| N-1 through N-8 | Original |
| AB-1 through AB-11/AB-12 | Original |

**Document History**

| Document Number | Status/Issue | Publication Date | CCR Number |
|---|---|---|---|
| 405-TDRS-RP-SY-011 | Original | December 8, 1995 | |
| 405-TDRS-RP-SY-011 | SCN-01 | 30 June 1998 | CCR-405-SY011-02/ TDRS Project CCR 8137 |

# Change Record

| Issue | Date | Affected Contents | Authority |
|---|---|---|---|
| SCN-01 | 30 June 1998 | SCN-01 incorporated ECP 002A, ECP 007, ECP 011 and TDRS CCR 8087. SCN-01 changes are highlighted on the pages as follows:<br><br>ECP 002A—pages xx, 2-1, 5-94, 5-94a/5-94b, 5-95, 5-122, 5-135, 5-136, 6-15, 8-25, B-46, B-60, K-6, K-7, K-14, k-16, k-17, L-5, L-7, L-9, L-12, M-1, M-11<br><br>ECP 007—pages 6-9, 6-10, 6-14, 6-15<br><br>ECP 011—pages L-1, L-2, L-2a/ L-2b, L-4<br><br>TDRS 8087—pages 5-44, B-11, K-20 | TDRS Project CCR 8137 |

# Section 2. Applicable and Reference Documents

## 2.1 Applicable Documents

The following documents, of the exact date of issue indicated, are part of this specification to the extent cited herein. If there are conflicts between the listed documents and the requirements of this specification, the requirements of this specification shall take precedence. In the event of conflict between other listed documents, the order of precedence shall be as follows:

a. The requirements of NASA documents shall take precedence over the requirements of other listed documents.

b. The requirements of other Government documents shall take precedence over contractor documents and industrial standards.

Where no section number is shown, the whole document shall apply.

### 2.1.1 NASA Documents

| Document Number | Document Title |
|---|---|
| 405-F7-ICD-001, 10/93 | TDRS F-7 Interface Control Document for the TDRS Spacecraft/Ground Segment |
| 405-TDRS-RP-SY-001, rev. E, ~~11/9/95~~ SCN-01, 6/30/98 | TDRS H, I, J Technical Requirements Specification |
| 405-TDRS-RP-ICD-001, SCN-01, 6/30/98~~10/95~~ | Interface Control Document (ICD) Between the Network Control Center (NCC)/Flight Dynamics Facility (FDF) and the White Sands Complex (WSC) for the TDRS H, I, J Era |
| GSFC-GA-GEM-1331331, 6/72 | Contractor Administered Training Course, Sections 6, 9, 12 |
| GSFC-STDN-SPEC-1, 9/85 | Specification Preparation and Acceptance of Technical Manuals |
| GSFC-STDN-SPEC 3, 9/85 | Specification for Programming and Handling Semiconductor Devices |
| GSFC-STDN-SPEC-4, 10/86 | General Requirements for STDN Electronic Equipment |
| GSFC-STDN-SPEC-5, 5/86 | Electronic Equipment Racks |
| GSFC-STDN-SPEC-6, 5/86 | Installation Requirements for STDN Equipment |
| GSFC-STDN-SPEC-7, 10/86 | Grounding System Requirements for STDN Stations |

### 5.2.1.3.2.4 Doppler Compensation

Doppler compensation requirements shall be as indicated below:

a. The frequency error (in Hz) after Doppler compensation shall be not more than 500 x $\ddot{R}$, for $\ddot{R} \leq 15$ m/sec$^2$ and $\dot{R} \leq 12$ km/sec; $\dot{R}$ and $\ddot{R}$ are the user spacecraft velocity and acceleration, respectively, relative to the assigned TDRS.

b. Doppler compensation shall not be required for $\dot{R} > 12$ km/sec.

c. The commanded frequency compensation shall be represented by a straight line (linear chord) plot of frequency vs. time, using a series of phase-continuous frequency steps.

d. The maximum forward carrier frequency and PN chip rate compensation, provided by the SGLT (exclusive of acquisition sweep requirements below) shall be as indicated in Table 5-15.

***Table 5-15. KSAF and KSHF Doppler Compensation Requirements***

| MAXIMUM CARRIER FREQUENCY DYNAMICS BEFORE COMPENSATION | | | PN CHIP RATE DYNAMICS BEFORE COMPENSATION | | |
|---|---|---|---|---|---|
| MAXIMUM DOPPLER kHz | MAX FREQ. RATE Hz/sec | MAX FREQ. ACCELERATION Hz/sec$^2$ | MAXIMUM DOPPLER Kchip/sec | MAX FREQ. RATE chip/sec$^2$ | MAX FREQ. ACCELERATION chip/sec$^3$ |
| ± 552 | ± 700 | ± 1.0 | ± 0.13 | ± 0.16 | ± 0.0022 |
| NOTE<br>BASED ON: $\dot{R}$ = 12 km/sec<br>$\ddot{R}$ = 15 m/sec$^2$<br>$\dddot{R}$ = 0.02 m/sec$^3$ | | | | | |

e. The forward link Doppler compensation shall follow a commanded profile which can accommodate any combination of the full range of parameters in Table 5-15.

f. Forward link carrier and PN code sweep (when commanded) shall be linear from an initial value of $F_o$ - 30 kHz to a final value of $F_o$ + 30 kHz in 120 sec, and chip rate from - 6.6 chips/sec to + 6.6 chips/sec; $F_o$ is the nominal RF carrier frequency (i.e., 14.625 GHz for KSA1 and 15.200 GHz for KSA2). The sweep shall not impact Doppler compensation requirements.

g. KSAF Doppler compensation shall not increase the effective frequency rate of change seen at the user spacecraft more than 330 Hz/sec relative to the frequency for a Doppler-free carrier.

12 dB greater.

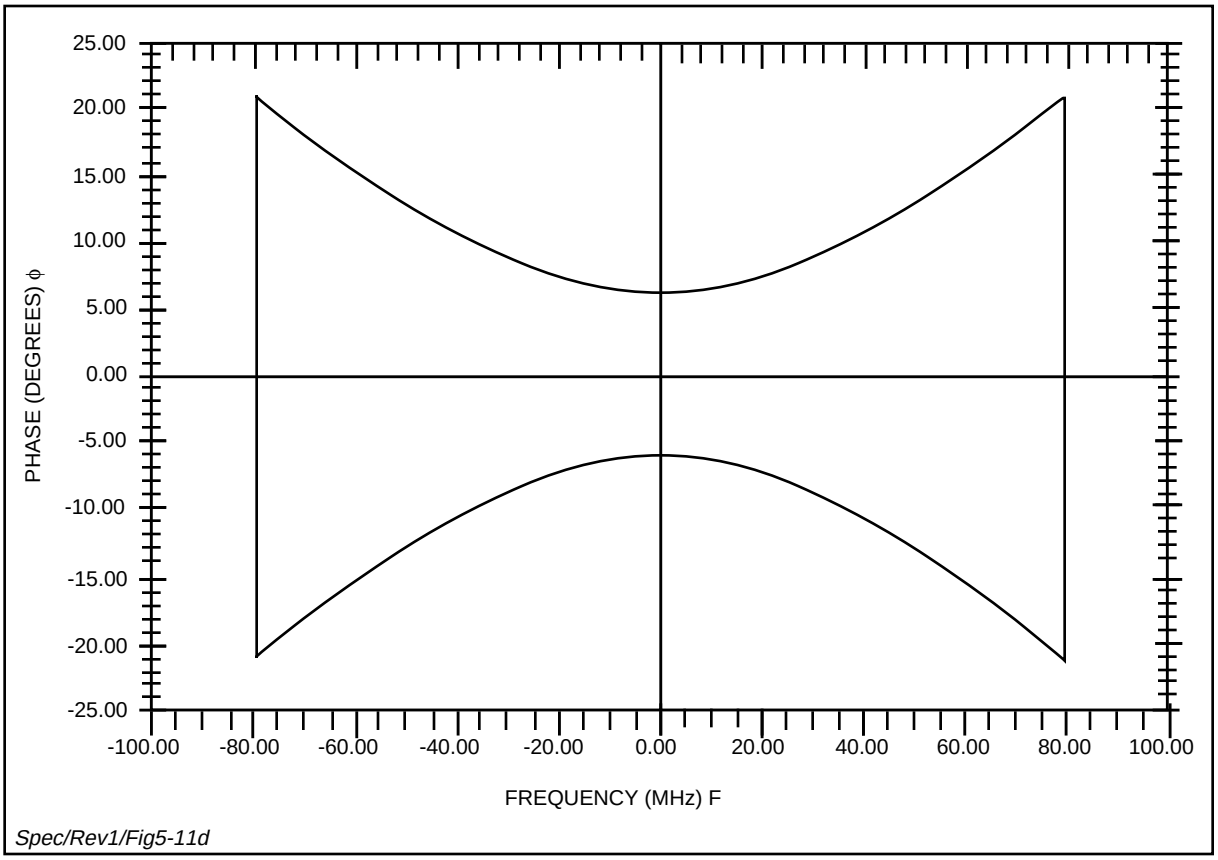


***Figure 5-11d. TDRS Induced KSAR Phase Distortion Region***

### 5.2.2.3.2.7 Acquisition Performance

For signal acquisition, the SGLT will be provided with vectors describing the user spacecraft dynamics in accordance with Appendix E. The vectors will include an epoch time uncertainty of $\leq \pm 4.5$ seconds.

a. Autotrack Acquisition. For TDRS F1-F7, a~~A~~utotrack acquisition time shall be measured from the instant at which user signal energy is present at the KSA autotrack signal processing input until autotrack acquisition is achieved. Autotrack acquisition is achieved for TDRS F1-F7 when the autotrack error signals are being used to maintain the required 0.06° ~~(for TDRS F1-F7) and 0.04° (TBR) (for TDRS H, I, J)~~ circular pointing error. For TDRS H, I, J, the auto track acquisition time shall be measured from the instant at which user signal presence is declared at the ground KSA autotrack receiver input, and ends when the autotrack error signals are being used to maintain continuous alignment of the SAA boresight axes with the USAT with an accuracy sufficient to provide the required autotrack mode EIRP specified for forward service and autotrack acquisition or steady state G/T specified for return service. The following acquisition performance requirements shall apply:

1. Autotrack acquisition shall be achieved within 10 seconds with a probability > 0.99 for $C/N_o$'s 6 dB below those values specified in Table 5-27~~.~~ for TDRS F1-F7 and TDRS H,I,J.

1a. For TDRS H, I, J, the autotrack acquisition and steady state autotrack performance shall be as specified in Table 5-27a with a probability >0.99.

***Table 5-27a. TDRS H, I, J Acquisition Time and G/T Performance***

| PARAMETER | KSA | KaSA |
|---|---|---|
| 1. USAT AXIAL RATIO | ≤ 3.0 dB | ≤ 1.0 dB |
| 2. AUTOTRACK ACQUISITION<br>A. ACQUISITION TIME<br>B. G/T MINIMUM | ≤ 10 SEC[1]<br>23.8 dB/K | ≤ 10 SEC[1]<br>TBP |
| 3. STEADY-STATE AUTOTRACK<br>A. ACQUISITION TIME<br>B. G/T MINIMUM | ≤ 45 (TBR) SEC[2]<br>24.4 dB/K | ≤ 45 (TBR) SEC[2]<br>26.5 dB/K |

NOTES

[1]THE 10 SECOND ACQUISITION TIME SHALL BE MEASURED FROM THE INSTANT AT WHICH USER SIGNAL PRESENCE IS DECLARED AT THE GROUND KSA AUTOTRACK RECEIVER INPUT.

[2]THE 45 (TBR) SECOND (I.E., THE MAXIMUM STEADY-STATE AUTOTRACK ACQUISITION TIME) ACQUISITION TIME SHALL BE MEASURED FROM THE INSTANT AT WHICH USER SIGNAL PRESENCE IS DECLARED AT THE GROUND KSA AUTOTRACK RECEIVER INPUT.

2. For TDRS F1-F7 and TDRS H, I, J, ~~A~~autotrack acquisition and subsequent autotracking shall be achieved for user incidental amplitude modulation (AM) of ≤ 5%, peak (< 0.6%, 10 Hz to 2 kHz; and < 3.0%, 10 Hz to 10 kHz) and in-band, incidental AM added by TDRS F1-F7 and TDRS H, I, J, ≤ 1%. The 5% peak user incidental AM applies at frequencies > 10 Hz for data rates < 1 kbps, and at frequencies > 100 Hz for data rates ≥ 1 kbps.

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3. The specified $C/N_o$ is referenced at the SGLT ground antenna input.

4. In the event that autotrack acquisition does not occur within the time specified, for TDRS F1-F7 and TDRS H, I, J, the acquisition process shall continue until autotrack acquisition occurs, or until a reacquisition is requested, or until the end of scheduled service.

b. PN Code Carrier Acquisition. Acquisition time shall be measured from the instant at which signal energy is present at the receiver/demodulator input and shall include the time to acquire the PN code (if applicable) and carrier. The following acquisition performance requirements shall apply:

1. The KSAR acquisition time shall not exceed the values specified in Table 5-27, for the $C/N_o$ values shown and the signal dynamics indicated in Section 5.2.2.3.2.2e.

2. The specified $C/N_o$ is referenced at the SGLT ground antenna input.

3. The probability of acquisition ($P_{acq}$) for the times specified in Table 5-27 shall be $\geq 0.9$.

4. When PN code acquisition is required, the time to acquire includes time to search the PN code uncertainty.

5. In the event that acquisition does not occur within the time specified, the PN code shall be searched until acquisition occurs, or until a reacquisition is requested, or until the end of scheduled service.

c. Symbol Synchronization (Uncoded Data Only). Symbol Synchronization time shall be measured from the time carrier acquisition is achieved to the time symbol synchronization is achieved. Symbol Synchronization is defined as having been achieved when the error rate for the next 1000 bits is $10^{-5}$ or less.

For the minimum data transition density and the minimum specified $C/N_o$ values required for $10^{-5}$ $P_E$ performance, the time to achieve symbol synchronization shall not exceed the following specified values:

1. 300/(data rate in bps) for Biphase symbol formats, with 90% probability.

2. 3000/(data rate in bps) for NRZ symbol formats, with 90% probability.

d. Symbol/Decoder Synchronization (Coded Data Only). Symbol/Decoder Synchronization time shall be measured from the time carrier acquisition is achieved to the time decoder synchronization is achieved. Decoder synchronization is achieved when the Viterbi decoder has selected and implemented the correct blocking of the input symbols (into groups of (G1, G2) symbol pairs). Requirements for bit error probability and symbol slipping take effect at the time decoder synchronization is achieved.

For the purposes of decoder synchronization, the minimum data bit transition density is 64 randomly distributed data bit transitions within any sequence of 512 data bits with no more than 64 consecutive data bits without a transition. For the minimum symbol and data transition densities and the minimum specified $C/N_o$ values required for $10^{-5}$ $P_E$ performance, the time to achieve symbol/decoder synchronization (in seconds) shall not exceed the following specified values:

### 5.3.3.2 RF Receive Component

The RF Receive Component shall consist of all the necessary equipment to satisfy the following performance requirements from the interface with the SGLT Ku-band Antenna Subsystem to the interface with the telemetry receiver processing. In the TTCS functional diagram, Figure 5-16, this component is shown as amplification, downconversion, and signal splitting.

#### 5.3.3.2.1 Input Signal Characteristics

The input signal to the RF Receive Component shall have the following characteristics:

| | | |
|---|---|---|
| a. | Telemetry Carrier Center Frequency | 13731.0 MHz |
| b. | Telemetry carrier effective long term (10 years) frequency stability: | |
| | 1. With pilot tone available for the TDRS spacecraft Master Frequency Generator | ± 80 kHz (max) |
| | 2. Without pilot tone | ± 100 kHz (max) |
| c. | Doppler Offset (one-way) Synchronous orbit | ± 2 kHz (max) |
| d. | Received isotropic total signal | -198.3 dBW (min)<br>~~-180.0~~ -165.0 dBW (max) |
| e. | Spurious signals<br>Sum of all in-band spurs | ≥ 27.9 dB below unmodulated carrier |
| | Discrete in-band spur | ≥ 40 dB below unmodulated carrier |
| f. | Incidental amplitude modulation | ≤ 2% |
| g. | Incidental discrete in-band phase modulation | ≥ 40 dB below unmodulated carrier |
| h. | Received isotropic carrier level | -207.3 dBW (min)<br>~~-180.0~~ -165.0 dBW (max) |
| i. | Received isotropic telemetry subcarrier level | -203.9 dBW (min)<br>~~-180.0~~ -165.0 dBW (max) |

synchronization clock pulse. The TTCS shall provide frame synchronization status information to the TT&C ADPE Subsystem that includes the modes specified below.

b. Frame Synchronization Strategy. Programmable frame synchronization capability shall be provided to allow the specification of frame synchronization strategy to recover TDRS telemetry data in an error-free environment, in a high-noise environment, and in the presence of a limited set of spacecraft failures. In particular, the frame synchronization strategy shall enable the specification of allowable errors in the frame sync pattern, the number of acceptable frame sync patterns necessary to change from search to verify, verify to lock, and to drop from lock to either of the other modes. Similar capability shall be provided for subframe synchronization strategy. Table 5-40 shall be used as a guide in the selection of a consistent set of parameters.

c. Telemetry Read Modes. The capability shall be provided to deliver telemetry data to the TT&C ADPE Subsystem under the following selectable modes:

1. Frame lock and subframe lock (normal operation).
2. Frame lock and no subframe lock.
3. Subframe lock and no frame lock.
4. Neither frame lock nor subframe lock.

### 5.3.3.7.2 Data Output to TT&C ADPE Subsystem

After demodulation of the telemetry subcarrier and obtaining bit and frame synchronization, the telemetry frames shall be transferred to the TT&C ADPE Subsystem.

***Table 5-39. Telemetry Signal Characteristics And Performance***

| | |
|---|---|
| A. RESERVED~~CARRIER ACQUISITION TIME - $P_{ACQ} \geq 0.9$~~ | ~~≤ 20 SEC. FOR CARRIER LEVEL GREATER THAN 9 dB ABOVE MIN.~~ |
| B. SIDEBAND PHASE-LOCK PROBABILITY | ≤ 0.01 |
| C. MODULATION INDEX - TELEMETRY DATA | 1.2 ± 10% RADIANS |
| D. MODULATION INDEX - RANGE TONE<br>IF A BINOR IMPLEMENTATION IS USED:<br>1. MAJOR TONE<br>2. MINOR TONE<br>IF A STDN IMPLEMENTATION IS USED:<br>1. MAJOR TONE<br>2. MINOR TONE | <br><br><br>0.35 ± 31% RADIANS<br>0.28 ± 31% RADIANS<br><br>0.40 ± 24% RADIANS<br>0.40 ± 24% RADIANS |
| E. SUBCARRIER FREQUENCY | 1.024 MHz ± 0.003% |
| F. SUBCARRIER MODULATION | PSK, BY NRZ-L DATA |
| G. TELEMETRY DATA RATE | 250, 1000 AND 4000 bps, AS DESIGNATED BY TT&C ADPE SUBSYSTEM |
| H. DATA RATE VARIATION | ≤ 1% |

*Table 5-39. Telemetry Signal Characteristics And Performance (Continued)*

| | |
|---|---|
| I. OUTPUT PROBABILITY OF ERROR | $\leq 10^{-5}$ FOR $E_b/N_o \geq 11.6$ dB |
| J. SUBCARRIER AND BIT SYNC ACQUISITION TIME | $\leq$ 2560 BITS FOR $E_b/N_o > 8.3$ dB AND TRANSITION DENSITY > 25% |

*Table 5-40. Frame Synchronization Protocol*

| MODES | PROTOCOL | RANGE |
|---|---|---|
| 1. ALL MODES | NUMBER OF BIT ERRORS ALLOWED PER ACCEPTABLE SYNC PATTERN | 0-3 ($N_1$) |
| 2. SEARCH MODE | NUMBER OF CONSECUTIVE ACCEPTABLE SYNC PATTERNS DETECTED BEFORE MOVING TO VERIFY MODE | 1-5 ($N_2$) |
| 3. VERIFY MODE | NUMBER OF CONSECUTIVE ACCEPTABLE SYNC PATTERNS VERIFIED BEFORE MOVING TO LOCK MODE | 1-9 ($N_3$) |
| 4. LOCK MODE | NUMBER OF CONSECUTIVE NON ACCEPTABLE SYNC PATTERNS DETECTED BEFORE REVERTING TO VERIFY MODE | 0-5 ($N_4$) |
| 5. REVERIFY | NUMBER OF CONSECUTIVE NONACCEPTABLE SYNC PATTERNS DETECTED BEFORE REVERTING TO SEARCH MODE | 0-5 ($N_5$) |
| NOTE<br>PARAMETERS $N_1$, $N_2$, $N_3$, $N_4$ AND $N_5$ SHALL BE SELECTABLE FROM THE RANGE OF VALUES INDICATED ABOVE. | | |

### 5.3.3.7.3 GSTDN Input

Input to the bit synchronizer shall be capable of manual connection through a connector so that digital telemetry can be received via the DIS.

### 5.3.3.7.4 Manual Control

Panel controls shall be available to manually override the TT&C ADPE Subsystem and to set the telemetry data rate to 250 bps, 1 kbps, or 4 kbps. The telemetry data rate shall also be controlled by the TT&C ADPE Subsystem.

### 5.3.3.7.5 Output to the Strip Chart Recorder Equipment

Output of the recovered serial NRZ-L encoded data from the frame synchronizer shall be available to a strip chart recorder which shall be capable of displaying up to sixteen TDRS telemetry parameters. The sixteen parameters to be displayed shall be selectable at the frame synchronizer and at TOCC workstations and Local MMI. Operational default values of selectable parameters shall be provided. Strip chart recorder pen calibrations shall be provided with a fixed pen cycle rate.

## *Table 6-1. Transmit RF Characteristics*

| | | |
|---|---|---|
| A. | TRANSMIT FREQUENCY (SELECTABLE ON TDRS HIJ ONLY) | 2.0359625 GHz (F1)<br>2.03043751~~81875~~ GHz (F2) (TDRS HIJ ONLY) |
| B. | RF BANDWIDTH (3 dB) | 3 MHz, MINIMUM |
| C. | EIRP (MINIMUM INCLUDING POINTING LOSS) | 70.5 dBW |
| D. | TRANSMIT GAIN | 43.5 dBi, MINIMUM |
| E. | SIDELOBE PATTERN[1] | G = 52-10log(D/λ)-25log(θ) dBi,<br>FOR 100 $\frac{\lambda}{D} \leq \theta \leq \frac{D}{5\lambda}$ WHERE<br>G = GAIN (IN dB) AT ANY FREQUENCY IN THE SPECIFIED FREQUENCY BAND OF SIDELOBE ENVELOPE RELATIVE TO AN ISOTROPIC ANTENNA AND θ IS THE OFF-BORESIGHT ANGLE IN DEGREES.<br>D = DIAMETER OF ANTENNA (METERS)<br>λ = WAVELENGTH AT TRANSMIT FREQUENCY (METERS) |
| F. | POLARIZATION | RIGHT HAND CIRCULAR |
| G. | ANTENNA AXIAL RATIO | 2 dB, MAXIMUM |

NOTE

[1]AT ANY FREQUENCY IN THE SPECIFIED BAND, NO SIDELOBE PEAK SHALL EXCEED THIS BOUND BY MORE THAN 3 dB. NO MORE THAN 10% OF THE SIDELOBE PEAKS SHALL EXCEED THE SPECIFIED BOUND.

## *Table 6-2. Receive RF Characteristics*

| | | |
|---|---|---|
| A. | RECEIVE FREQUENCY (SELECTABLE ON TDRS HIJ ONLY) | 2.211 GHz (F1)<br>2.2050~~65~~ GHz (F2) (TDRS HIJ ONLY) |
| B. | RF BANDWIDTH (3 dB) | 3 MHz, MINIMUM |
| C. | G/T[1] | 18.5 dB/°K, MINIMUM |
| D. | SIDELOBE PATTERN[2] | G = 52-10log(D/λ)-25log(θ) dBi,<br>FOR 100 $\frac{\lambda}{D} \leq \theta \leq \frac{D}{5\lambda}$ WHERE<br>G = GAIN (IN dB) AT ANY FREQUENCY IN THE SPECIFIED FREQUENCY BAND OF SIDELOBE ENVELOPE RELATIVE TO AN ISOTROPIC ANTENNA AND θ IS THE OFF-BORESIGHT ANGLE IN DEGREES.<br>D = DIAMETER OF ANTENNA (METERS)<br>λ = WAVELENGTH AT RECEIVE FREQUENCY (METERS) |
| E. | POLARIZATION | RIGHT HAND CIRCULAR |
| F. | ANTENNA AXIAL RATIO | 2 dB, MAXIMUM |

NOTES

[1]THE SPECIFIED G/T PERFORMANCE (CLEAR SKY) SHALL INCLUDE POINTING LOSS (AT ELEVATION ANGLES OF 5° OVER THE LOCAL HORIZON AND WHENEVER THE SUN IS ± 4° OR GREATER OFF THE ANTENNA BORESIGHT) AND SHALL INCLUDE THE TOTAL CONTRIBUTION FROM THE LNA, ASSOCIATED WAVEGUIDE SWITCHES, COUPLERS AND OUTPUT WAVEGUIDES.

[2]AT ANY FREQUENCY IN THE SPECIFIED BAND, NO SIDELOBE PEAK SHALL EXCEED THIS BOUND BY MORE THAN 3 dB. NO MORE THAN 10% OF THE SIDELOBE PEAKS SHALL EXCEED THE BOUND.

## *Table 6-3. Mechanical Characteristics*

| | | |
|---|---|---|
| A. | AXIS CONFIGURATION | ELEVATION OVER AZIMUTH |
| B. | ANGULAR COVERAGE | |
| | 1. AZIMUTH | ± 165° (DEAD ZONE NORTH) |
| | 2. ELEVATION | 0° TO + 92° |
| C. | ANGULAR DYNAMIC CAPABILITY (EACH AXIS) | |
| | 1. ANGULAR VELOCITY | 0.002°/SEC to 2°/SEC |
| | 2. ANGULAR ACCELERATION | 1°/SEC[2] |
| D. | WINDS | |
| | 1. SURVIVAL-ANY POSITION | UP TO 130 km/HOUR |
| | 2. SURVIVAL-STOW POSITION | UP TO 193 km/HOUR |

## 6.3 S-band TT&C Ground Equipment (STGE)

### 6.3.1 Functional Requirements

The STGE functional requirements shall be as specified in Section 5.3.2 with the following exceptions:

a. Frequency upconversion to S-band (instead of K-band) shall be required (Transmit).

b. The switching capability to distribute the RF output to the Antenna Subsystem (instead of the RF Power Combiner) or the dummy load shall be provided (Transmit).

c. Pilot tone generation is not applicable.

d. Frequency downconversion from S-band (instead of K-band) shall be required (Receive).

e. The switching capability to select RF input from either the Antenna Subsystem (instead of the RF Power Divider) or the PMMS test equipment shall be provided (Receive).

### 6.3.2 Performance Requirements

The S-band TT&C Ground Equipment performance shall be as specified below.

#### 6.3.2.1 RF Transmit Component

The RF Transmit Component requirements shall be as specified in Section 5.3.3.1 with the following exceptions:

| | | |
|---|---|---|
| a. | Uplink Center Frequency (selectable on TDRS HIJ only) | F1: 2.0359625 GHz<br>F2: 2.03<u>04375</u>~~181875~~ GHz (TDRS HIJ only) |
| b. | Power Output | 2 KW (nominal) |
| c. | S-band phase noise | 1 Hz to 1 kHz ≤ 1.0° rms<br>1 kHz to 3 MHz ≤ 0.5° rms |
| d. | Antenna Polarization | Right Hand Circular |
| e. | Transmit Signal-to-Thermal Noise Ratio (within ± 1.5 MHz of the carrier) | ≥ 50 dB at the EIRP given in Table 6-1 |

#### 6.3.2.2 RF Receive Component

The RF Receive Component shall consist of all the necessary equipment to satisfy the performance requirements specified below from the interface with the S-band Antenna Subsystem to the interface with the telemetry receiver processing. In the functional diagram, Figure 5-16, this component is shown as amplification, downconversion, and signal splitting.

#### 6.3.2.2.1 Input Signal Characteristics

The input signal to the RF Receive Component shall have the following characteristics:

| | | |
|---|---|---|
| a. | Telemetry Carrier Center Frequency (selectable on TDRS HIJ only) | F1: 2211.0 MHz<br>F2: 2205.0~~6.5~~ MHz (TDRS HIJ only) |
| b. | Telemetry carrier effective long term (10 years) frequency stability | ± 80 kHz (max) |
| c. | Doppler Offset (one-way) Synchronous orbit | ± 250 Hz (max) |
| d. | Received isotropic total signal | -201.8 dBW (min)<br>-181.8 dBW (max) |
| e. | Spurious Signals<br>RMS-Sum of all in-band spurs | ≥ 27.9 dB below unmodulated carrier |
| | Discrete in-band spurs | ≥ 40 dB below unmodulated carrier |
| f. | Incidental amplitude modulation | ≤ 2% |
| g. | Incidental discrete in-band phase modulation | ≥ 40 dB below unmodulated carrier |
| h. | Received isotropic carrier level | -208.4 dBW (min)<br>-181.8 dBW (max) |
| i. | Received isotropic telemetry subcarrier level | -207.8 dBW (min)<br>-181.8 dBW (max) |
| j. | Received isotropic ranging signal level | -221.4 dBW (min)<br>-181.8 dBW (max) |
| k. | Signal format | The telemetry signal format is specified in Section 5.3.3.7<br>The range signal format is specified in Section 5.3.3.5 |
| l. | Polarization | Right Hand Circular |

#### 6.3.2.2.2 Equipment Characteristics

The RF Receive Component equipment characteristics shall be as specified in Section 5.3.3.2.2 except carrier acquisition time ($P_{acq} \geq 0.9$. no ranging modulation during carrier acquisition) shall be ≤ 10 seconds with carrier $C/N_0 \geq 40$ dB-Hz.

#### 6.3.2.2.3 Output Signal Characteristics

For the input signal characterized in Section 6.3.2.2.1, the output signal characteristics of the RF Receive Component shall be as follows:

### 8.2.7.6 TDRS Telemetry and Command Data

The Communications Switch shall be capable of blocking TDRS command data and deblocking TDRS telemetry data, using the NASCOM TDRSS 4800 bit blocks. The 4800-bit block is defined in Appendix I.

#### 8.2.7.6.1 TDRS Telemetry Data

The TDRS Telemetry data received from GSTDN via GSFC shall be deblocked by the Communications Switch. After deblocking, the data shall be transmitted as bit contiguous data to the TT&C subsystems via the Black Data Switch at a rate of either 249.98 or 999.94 bps for TDRS F1-F7 as selected by the DIS ADPE.

#### 8.2.7.6.2 TDRS Command Data

The TDRS command data to GSTDN shall be received from TT&C subsystems via the Black Data Switch at a rate of 2 kbps and shall be blocked by the Communications Switch for transmission to GSTDN via the GSFC interface.

For TDRS command data, the Communications Switch shall format the 4800 bit block shown in Figure 8-3b using information received from the DIS ADPE Subsystem. The Communications Switch return port utilized for TDRS command data shall operate in either the clear mode or the encrypted mode, as specified below:

a. Clear Mode. (For TDRS F1-F7 only) The continuous 2 kbps NRZ-L ~~(TBR)~~ data and clock signals shall be received from the Black Data Switch. The Communications Switch shall discard idle (1,0) pattern bits and shall pack each 4800-bit block with an integral number of TDRS command words (40 bits each ~~for TDRS F1-F7; TBR bits each for TDRS HIJ~~). The 4800-bit blocks shall be transmitted at a one-block-per-second rate. The Communications Switch shall generate the polynomial error code remainder for each 4800-bit block.

b. Encrypted Mode. (For TDRS F1-F7 and TDRS H, I, J) The continuous 2 kbps NRZ-M encrypted or the 2 kbps NRZ-L unencrypted data and clock signals will be received from the Black Data Switch. The Communications Switch shall handle the NRZ-M data as if it were NRZ-L at the bit level. The Communications Switch shall pack 2000 bits into 4800-bit blocks, which shall be transmitted at a one-block-per-second rate. The Communications Switch shall generate the polynomial error code remainder for each 4800-bit block.

### 8.2.7.7 Communications Switching Connectivities

The Communications Switch shall be capable of providing the connectivities specified in Table 8-3. Based on data link quality and DIS equipment status information, the DIS ADPE Subsystem shall determine the appropriate prime/redundant path connectivities between all input ports and all output ports and shall display the appropriate connectivities to the DIS TOCC operator. The DIS ADPE Subsystem shall command and control the communications switching equipment configuration to implement the selected connectivities.

*Table B-5. Doppler Compensation Requirements - MAF Services*

| | Maximum Carrier Frequency Dynamics Before Compensation | | | Maximum PN Chip Rate Dynamics Before Compensation | | |
|---|---|---|---|---|---|---|
| Spacecraft | Maximum Doppler kHz | Max Freq. Rate Hz/sec | Max Freq Acceleration $Hz/sec^2$ | Maximum Doppler kchip/sec | Max Freq. Rate $chip/sec^2$ | Max Freq. Acceleration $chip/sec^3$ |
| F1-F7[1] | ± 85 | ± 110 | ± 0.152 | ± 0.13 | ± 0.16 | ± 0.00022 |
| HIJ[2] | ± 85 | ± 360 | ± 15 | ± 0.13 | ± 0.53 | ± 0.022 |

NOTES

1. BASED ON: $\dot{R}$ = 12 km/sec, $\ddot{R}$ = 15 $m/sec^2$, and $\dddot{R}$ = 0.02 $m/sec^3$

2. BASED ON: $\dot{R}$ = 12 km/sec, $\ddot{R}$ = 50 $m/sec^2$, and $\dddot{R}$ = 2 $m/sec^3$

### B.1.1.3.5 Performance Measuring and Monitoring Support

The performance requirements for performance measuring and monitoring shall be as specified in Section 5.2.1.3.1.6.

### B.1.1.4 Interfaces

The USS MAF equipment interface shall include the parameters and signals specified in Table B-6. Additional interfaces to the USS SSA service equipment shall be provided as required for the cross support communications and tracking services.

*Table B-6. MAF Equipment Interfaces*

| FROM | TO | PARAMETER/SIGNAL |
|---|---|---|
| MAF EQUIPMENT | MA TRACKING EQUIPMENT | FORWARD PN EPOCH PULSE<br>FORWARD PN CLOCK |
| CTFS | MAF EQUIPMENT | 1 PPS TIME TICKS<br>FREQUENCY STANDARD |
| DIS | MAF EQUIPMENT | BASEBAND USER FORWARD DATA<br>USER CLOCK SIGNAL |
| MA USS ADPE SUBSYSTEM | MAF EQUIPMENT | CONFIGURATION COMMANDS<br>EQUIPMENT CONTROL |
| MAF EQUIPMENT | MA ADPE SUBSYSTEM | EQUIPMENT STATUS DATA<br>SERVICE STATUS DATA<br>DPM MEASUREMENT DATA<br>TRACKING DATA |
| PMMS | MAF EQUIPMENT | BASEBAND TEST DATA |
| MAF EQUIPMENT | PMMS | FORWARD RF TEST SIGNALS |
| MAF EQUIPMENT | USS RF POWER COMBINER | FDM UPLINK SIGNAL |

### *Table B-8b. TDRS H,I,J MAR Allowable Implementation Loss, $L(P_E, R_b)$ - Rate 1/3 Coding*

| Data Channel Bit Rate $R_b$ (KBPS) | $E_b/N_O$ = ~~4.2~~3.9 dB $P_E = 10^{-5}$ | $E_b/N_O$ = ~~4.8~~4.5 dB $P_E = 10^{-6}$ | $E_b/N_O$ = 5.1~~4~~ dB $P_E = 10^{-7}$ |
|---|---|---|---|
| .1 | 2.5 | 2.7 | 3.0 |
| 1 | 2.5 | 2.7 | 2.9 |
| 10 | 2.5 | 2.7 | 2.9 |
| 100 | 2.5 | 2.7 | 2.9 |
| 1000 | 2.5 | 2.7 | 2.9 |
| 2000 | 3.0 | 3.2 | 3.7 |

(NOTES)

- For DG1 Modes 1,2 and I Channel of Mode 3, an additional Implementation Loss not to exceed 0.5 dB shall be allowed.
- For NRZ-M and NRZ-S Data Formats, an additional Implementation Loss of 0.1 dB shall be allowed.

### *TABLE B-10a TDRS H,I,J ADDITIONAL INPUT SIGNAL DISTORTIONS*

| SIGNAL CONSTRAINT | MAR |
|---|---|
| DATA ASYMMETRY | ≤ ±3% |
| DATA TRANSITION TIME | < 5% OF BIT TIME BUT NO LESS THAN 17 NSEC |
| DATA SKEW (RELATIVE TO REQUIREMENTS FOR I/Q DATA SYNCHRONIZATION) | ≤ 3% |
| I/Q PN CHIP SKEW (RELATIVE TO 0.50 CHIP) | ≤ 0.01 CHIP |
| PN CODE POWER SUPPRESSION | < 0.3 dB |
| MODE 2 PN CHIP RATE (RELATIVE TO ABSOLUTE COHERENCE WITH CARRIER RATE) | 0.01 Hz PEAK AT PN RATE |
| BPSK PHASE IMBALANCE | ≤ ±3 DEGREES |
| GAIN IMBALANCE | ≤ ±0.25 dB |
| QPSK PHASE IMBALANCE | 90 ±3 DEGREES |
| AM/PM | < 12 DEGREES/dB |
| SPURIOUS PM | < 3 DEGREES RMS (100 Hz TO ~~6~~3 MHz) |
| INCIDENTAL AM (3 SIGMA) (AT FREOUENCIES > 10 Hz FOR DATA RATES < 1 KBPS; AT FREQUENCIES > 100 Hz FORDATA RATES > 1 KBPS) | ≤ 6% |

**NOTE**

SIGNAL CONSTRAINT DEFINITIONS ARE PROVIDED IN APPENDIX N.

## *TABLE K-3. Forward Service Signal Distortion Characteristics*

| Parameter | MA | SSA | KSA |
|---|---|---|---|
| 1. I/Q power ratio tolerance(1) | ≤ 0.5 dB | ≤ 0.5 dB | ≤ 0.5 dB |
| 2. Modulator phase imbalance, peak (BPSK only) | ±3° | ±3° | ±3° |
| 3. Relative phase between command and range channels | 90° ± 3° | 90° ± 3° | 90° ± 3° |
| 4. Modulator gain imbalance, peak | ±0.25 dB | ±0.25 dB | ±0.25 dB |
| 5. Data asymmetry, peak | ±3% | ±3% | ±3% |
| 6. Data transition time (90% of initial state to 90% of final state) | ≤ 5% of data bit duration but ≥ 8 nsec | ≤ 5% of data bit duration but ≥ 8 nsec | ≤ 5% of data bit duration but ≥ 4 nsec |
| 7. Phase nonlinearity, peak-to-peak (applies for all types of phase nonlinearities) | ≤ 0.4 rad over ±2.1 MHz | ≤ 0.3 rad over ±7 MHz | ≤ 0.3 rad over ±17.5 MHz |
| 8. Gain flatness, peak-to-peak | ≤ 1.6 dB over ±2.1 MHz | ≤ 1.6 dB over ±7 MHz | ≤ 1.6 dB over ±17.5 MHz |
| 9. (Reserved) | | | |
| 10. AM/AM | > 0 dB/dB | > 0 dB/dB | > 0 dB/dB |
| 11. AM/PM | ≤ 10°/dB | ≤ 10°/dB | ≤ 7°/dB |
| 12. PN code chip jitter, rms (including effects of Doppler compensation) | ≤ 1° | ≤ 1° | ≤ 1° |
| 13. Data bit jitter, peak(2) | ≤ 1% | ≤ 1% | ≤ 1% |
| 14. Spurious PM, rms | ≤ 1° | ≤ 1° | ≤ 1° |
| 15. Spurious outputs | ≤ -27 dBc | ≤ -27 dBc | ≤ -27 dBc |
| 16. Frequency stability | | | |
| a. 1 to 100 sec average time | $< 9 \times 10^{-13}$ | $< 9 \times 10^{-13}$ | $< 9 \times 10^{-13}$ |
| b. 24-hr average time | $< 1 \times 10^{-12}$ | $< 1 \times 10^{-12}$ | $< 1 \times 10^{-12}$ |
| 17. Incidental AM, peak | ≤ 2% | ≤ 2% | ≤ 2% |
| 18. Phase noise, rms | | | |
| a. 1 Hz to 10 Hz | ≤ 1.5° | ≤ 1.5° | ≤ 1.5° |
| b. 10 Hz to 32 Hz | ≤ 1.5° | ≤ 1.5° | ≤ 1.5° |
| c. 32 Hz to 1 kHz | ≤ 4.0° | ≤ 4.0° | ≤ 4.0° |
| d. 1 kHz to 3 MHz | ≤ 2.0° | NA | NA |
| e. 1 kHz to ~~6~~10 MHz | NA | ≤ 2.0° | NA |
| f. 1 kHz to 25 MHz | NA | NA | ≤ 2.0° |
| 19. PN code chip skew, peak | ≤ 0.01 chip | ≤ 0.01 chip | ≤ 0.01 chip |
| 20. PN code chip asymmetry, peak | ≤ 0.01 chip | ≤ 0.01 chip | ≤ 0.01 chip |
| 21. PN code chip rate offset, peak (relative to absolute coherence with carrier) | ≤ 0.01 chip/sec | ≤ 0.01 chip/sec | ≤ 0.01 chip/sec |

**NOTES**:

1. For forward service with data rate ≤ 300 kb/sec, this tolerance applies to the ratio of the command channel power to the range channel power.

2. The total bit jitter is the sum of the weighted spurious and random jitter components.

### *TABLE K-4. Forward Service Parameters*

| Parameter | MA | SSA | KSA |
|---|---|---|---|
| 1. FOV, minimum | ±13° conical(1) | ±22.5° East-West<br>±31.0° North-South<br>Elliptical | ±22.5° East-West<br>±31.0° North-South<br>Elliptical |
| 2. Angular rate $\dot{\theta}$, maximum(2) | 0.036°/sec | 0.036°/sec | 0.0135°/sec |
| 3. Polarization | LHC | RHC or LHC, selectable | RHC or LHC, selectable |
| 4. Axial ratio, maximum | 1.5 dB over 3-dB formed beamwidth | 1.5 dB over 3-dB beam-width | 1.0 dB over 3-dB beamwidth |
| 5. Signal EIRP, minimum | | | |
| a. Program track mode(3) | 34.0 to 42.0 dBW adjust-able in ≤1.0 dB steps(1,4) | 36.3 to 48.5 dBW(4) adjust-able in ≤ 1.0 dB steps | 39.6 + X dBW(5,6) |
| b. Autotrack mode(6,7) | NA | NA | 39.0 to 49.0 dBW adjustable in ≤ 1.0 dB steps |
| 6. RF channel 3 dB bandwidth, ~~3 dB~~ minimum | 6 MHz | 20 MHz | 50 MHz |
| 7. C/N at output of TDRS H, I, J spacecraft antenna, minimum | 16 dB | 16 dB | 16 dB |

**NOTES*:***

1. For a FOV less than or equal to ±10.5° conical, the minimum EIRP shall be from 34 to 42 dBW adjustable in ≤1.0 dB steps. For a FOV greater than ±10.5° conical, and less than or equal to ±13° conical, the minimum EIRP shall be greater than 34 dBW.

2. $\dot{\theta}$ is the maximum angular rate for which service shall be provided. $\dot{\theta} = \sqrt{(\dot{\theta}_x)^2 + (\dot{\theta}_y)^2}$, where $\theta_x$ is the North-South component of the angle between the TDRS H, I, J spacecraft/nadir vector and the TDRS H, I, J spacecraft/USAT vector, and where $\theta_y$ is the East-West component.

3. EIRP toward USAT with open-loop antenna pointing.

4. With USAT ephemeris uncertainty of ±9 seconds, uniformly distributed along the USAT orbital track.

5. X is the loss in dB arising from a receiving USAT with a 6-dB antenna axial ratio.

6. With USAT ephemeris uncertainty of ±4.5 seconds, uniformly distributed along the USAT orbital track.

7. EIRP in the direction of the USAT during forward service in conjunction with return link autotrack.

### *TABLE K-5. Return Service Signal Parameters (continued)*

**NOTES:**

7. The data format shall be NRZ-L, M, S at the convolutional encoder input when convolutional coding is used.

8. The output of the convolutional encoder may be NRZ-to-Biϕ converted for MA and SSA. The output of the convolutional encoder may be NRZ-to-Biϕ converted for KSA I and Q data rates ≤ 5 Mb/sec. This capability shall not be used with symbol interleaving. No $G_2$ inversion shall occur in the convolutional encoder when NRZ-to-Biϕ conversion is performed.

9. Data signals on I and Q channels may be independent and asynchronous. If the I and Q channel data signals are independent, the sum of the data rates on the I and Q channels shall not exceed the total maximum data rate. For DG2 and for identical symbol rates on the I and Q channels, the I and Q channels will be offset relative to one another by one half symbol period. When Biϕ format conversion is used, the maximum data rates are reduced by a factor of 2. Rate 1/2 or rate 1/3 convolutional encoding is required for S-band return services. For DG1 S-band services, data rate restrictions apply to data prior to rate 1/2 coding; for DG1 mode 3 Q-channel rate 1/3 coding, data rate restrictions are reduced by a factor of 1.5. For KSA services, data rate restrictions apply to uncoded data; for rate 1/2 coding, data rate restrictions are reduced by a factor of 2. Rate 1/3 convolutional encoding is not applicable for KSA services. Biϕ data format will not be used for data rates >5 Mbps.

10. For rate 1/2 coding, the maximum Q channel data rate shall be 75 Mb/sec.

### *TABLE K-6. Return Service Parameters*

| Parameter | MA | SSA | KSA |
|---|---|---|---|
| 1. FOV, minimum | ±13° conical(1) | ±22.5° East-West<br>±31.0° North-South<br>Elliptical | ±22.5° East-West<br>±31.0° North-South<br>Elliptical |
| 2. Polarization | LHC | RHC or LHC, selectable | RHC or LHC, selectable |
| 3. Axial ratio, maximum | 1.5 dB over 3-dB formed beamwidth | 1.5 dB over 3-dB beamwidth | 1.0 dB over 3-dB beamwidth |
| 4. RF channel 3 dB bandwidth, ~~3 dB~~ minimum | 6 MHz | 10 MHz | 225 MHz |

**NOTES:**

1. For a FOV less than or equal to ±10.5° conical, the TDRS H, I, J spacecraft minimum G/T is 4.5 dB/K. For a FOV greater than ±10.5° conical, and less than or equal to ±13° conical, the TDRS H, I, J spacecraft minimum G/T is -1.5 dB/K.

*TABLE K-7. Return Service USAT Signal Distortion Constraints (continued)*

| Parameter | MA | SSA | KSA |
|---|---|---|---|
| 13. Symbol jitter and jitter rate[1,3] | ≤ 0.1% | ≤ 0.1% | ≤ 0.1% |
| 14. Spurious PM, rms | ≤ 2° | ≤ 2° | ≤ 2° |
| 15. Spurious outputs | | | |
| a. Within data bandwidth | ≤ -30 dBc | ≤ -30 dBc | ≤ -30 dBc |
| b. Between data bandwidth and channel bandwidth | ~~≤ -15 dBc~~NA | ~~≤ -15 dBc~~NA | ≤ -15 dBc |
| b1. Between data bandwidth and 2 times channel bandwidth | ≤ -15 dBc | ≤ -15 dBc | NA |
| c. Between channel bandwidth and 2 times channel bandwidth | ~~≤ -15 dBc~~NA | ~~≤ -15 dBc~~NA | ≤ -25 dBc |
| d. Outside of 2 times channel bandwidth | ≤ -30 dBc | ≤ -30 dBc | ≤ -30 dBc |
| 16. Frequency stability, peak | | | |
| a. 1 sec average time | ≤ $3 \times 10^{-9}$ | ≤ $3 \times 10^{-9}$ | ≤ $3 \times 10^{-9}$ |
| b. 5 hr average time | ≤ $1 \times 10^{-7}$ | ≤ $1 \times 10^{-7}$ | ≤ $1 \times 10^{-7}$ |
| c. 48 hr average time | ≤ $3 \times 10^{-7}$ | ≤ $3 \times 10^{-7}$ | ≤ $3 \times 10^{-7}$ |
| 17. Incidental AM, peak | | | |
| a. At frequencies ≥ 10 Hz for data rates < 1 kb/sec and at frequencies > 100 Hz for data rates ≥ 1 kb/sec | ≤ 5% | ≤ 5% | NA |
| b. ~~At frequencies ≤ 2 kHz~~For autotrack | NA | NA | ≤ 0.6% 10 Hz-2 kHz |
| ~~c. At frequencies between 2 kHz and 10 kHz~~ | ~~NA~~ | ~~NA~~ | ≤ 3% 10 Hz – 10 kHz |
| ~~d. At frequencies ≥ 10 kHz~~ | ~~NA~~ | ~~NA~~ | ~~≤ 5%~~ |
| 18. Phase noise, rms | | | |
| a. Coherent turnaround (assumes 0° forward link phase noise) | | | |
| (1) 1 Hz to 10 Hz | ≤ 1.0° | ≤ 1.0° | ≤ 3.0° |
| (2) 10 Hz to 1 kHz | ≤ 1.0° | ≤ 1.0° | ≤ 3.0° |
| (3) 1 kHz to 3 MHz | ≤ 1.0° | NA | NA |
| (4) 1 kHz to 6 MHz | NA | ≤ 1.0° | NA |
| (5) 1 kHz to 150 MHz | NA | NA | ~~≤ 2.0°~~1.0° |

*TABLE K-7. Return Service USAT Signal Distortion Constraints (continued)*

| Parameter | MA | SSA | KSA |
|---|---|---|---|
| b. Non-coherent TCXO (return link not coherently related to forward link) | | | |
| (1) 1 Hz to 10 Hz | ≤ 2.0° | ≤ 2.0° | ≤ 15.0° |
| (2) 10 Hz to 100 Hz | ≤ 1.0° | ≤ 1.0° | ≤ 7.5° |
| (3) 100 Hz to 1 kHz | ≤ 1.0° | ≤ 1.0° | ≤ 2.0° |
| (4) 1 kHz to 3 MHz | ≤ 1.0° | NA | NA |
| (5) 1 kHz to 6 MHz | NA | ≤ 1.0° | NA |
| (6) 1 kHz to 150 MHz | NA | NA | ≤ ~~1~~2.0° |
| c. Non-coherent TCXO with USO (return link not coherently related to forward link) | | | |
| (1) 1 Hz to 10 Hz | ≤ 1.0° | ≤ 1.0° | ≤ 5.9° |
| (2) 10 Hz to 100 Hz | ≤ 1.0° | ≤ 1.0° | ≤ 7.4° |
| (3) 100 Hz to 1 kHz | ≤ 1.0° | ≤ 1.0° | ≤ 2.0° |
| (4) 1 kHz to 3 MHz | ≤ 1.0° | NA | NA |
| (5) 1 kHz to 6 MHz | NA | ≤ 1.0° | NA |
| (6) 1 kHz to 150 MHz | NA | NA | ≤ ~~1~~2.0° |
| 19. I/Q symbol skew, peak (relative to requirements for I/Q data synchronization, where appropriate) | ≤ 3% | ≤ 3% | ≤ 3% |
| 20. I/Q PN code chip skew (relative to 0.50 chip) | ≤ 0.01 chip | ≤ 0.01 chip | ≤ 0.01 chip |
| 21. PN code chip rate offset, peak (relative to absolute coherence with carrier) | ≤ 0.01 chip/sec | ≤ 0.01 chip/sec | ≤ 0.01 chip/sec |
| 22. Maximum user EIRP | 45 dB W | 45 dBW | 60 dBW |
| 23. Axial ratio for autotrack[4] | NA | NA | ≤ 3.0 dB |

**NOTES**:

1. For uncoded data, the symbol parameters should be interpreted as data bit parameters.
2. For the purposes of minimum bandwidth definition, the symbol rate for Biϕ formatted data shall be twice the symbol rate prior to NRZ-to-Biϕ data format conversion.
3. The symbol jitter and jitter rate are defined in Section 5.2.2.3.2.2.l as the user transmitted peak clock frequency jitter and peak clock jitter rate (sinusoidal or 3σ random) as a percent of the symbol clock rate. Jitter and jitter rates greater than 0.1% and less than or equal to 2.0% are applicable to KSHR service only.
4. Applies to TDRSS return link only.

*TABLE K-9. Return Service Data Coding Configurations*

| Data Configuration[1] | | Convolutional Codes[3] | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| **Single data channel** | DG1, mode 1 & 2 | MA, SSA, KSA | NA | NA |
| | DG1, mode 3[2] | MA, SSA, KSA | NA | MA, SSA |
| | DG2 | MA, SSA, KSA | MA, SSA (BPSK only) | MA, SSA |
| **Dual data channel** | DG1, mode 1 & 2 | MA, SSA, KSA | NA | NA |
| | DG1, mode 3 | MA, SSA, KSA | NA | MA, SSA |
| | DG2 | MA, SSA, KSA | NA | MA, SSA |

**NOTES**:

1. For S-band service, interleaving is required for symbol rates > 300 ks/sec as specified in 405-TDRS-RP-SY-001, Appendix D.
2. DG1 mode 3 may provide a single data channel on the Q channel and the range PN code on the I channel without data modulation on the I channel.
3. Convolutional codes are as specified in K.1.3.2.f.

(7) For S-band service at symbol rates > 300 ks/sec, symbol interleaving shall be used as specified in 405-TDRS-RP-SY-001, Appendix D.

g. **USAT dynamics**

(1) TDRSS shall be capable of providing return services to USATs with dynamics as specified in Table K-10.

*TABLE K-10. USAT Dynamics*

| Parameter[1] | Free Flight | Powered Flight[2] | |
|---|---|---|---|
| | | Non-Shuttle[3] | Shuttle[2] |
| $\dot{R}$ | ≤ 12 km/sec | ≤ 15 km/sec | ≤ 12 km/sec |
| $\ddot{R}$ | ≤ 15 m/sec$^2$ | ≤ 50 m/sec$^2$ | ≤ 50 m/sec$^2$ |
| $\dddot{R}$ | ≤ 0.02 m/sec$^3$ | ≤ 2 m/sec$^3$ | ≤ 2 m/sec$^3$ |

**NOTES**:

1. R is the USAT-to-TDRS H, I, J spacecraft range.
2. Supported by SSA only.
3. Supported by SSA and MA.

(2) In addition, TDRSS shall be capable of providing program track return service to S-band USATs with a maximum angular rate of 0.036°/sec.

# Appendix L. Requirements for KaSA Service via the TDRS H, I, J Spacecraft

**L.1 Introduction**. This appendix provides the technical requirements for a Ka-band Single Access (KaSA) service via the TDRS H, I, J spacecraft. Currently, NASA has been assigned the primary allocation for space exploration service in the Ka-band.

KaSA forward services will use frequencies within the range 22.55 GHz to 23.55 GHz and the same signal parameters as KSA forward services. ~~with the exception that the command channel PN code will be inhibited.~~

KaSA return services will use frequencies within the range 25.25 GHz to 27.50 GHz and the same signal parameters as KSA DG2 non-coherent return services.

The SGL will be at Ku-band. To the maximum extent practicable, the KaSA service should use the existing KSA equipment from the Danzante and Cacique ground terminals without modification.

Definitions of distortion parameters are given in Appendix N.

**L.2 Telecommunications service requirements** Each TDRS H, I, J spacecraft, in conjunction with the WSC, shall be capable of supporting KaSA telecommunications services for USATs as specified herein.

### L.2.1 *Forward service requirements*

a. **Service requirements**

(1) Each TDRS H, I, J spacecraft, in conjunction with the WSC, shall be capable of providing the following combinations of Ku-band and Ka-band single access forward services:

(a) 2 KSA forward services, or

(b) 1 KSA forward service and 1 KaSA forward service, or

(c) 2 KaSA forward services.

(2) Each TDRS H, I, J spacecraft, in conjunction with the WSC, shall be capable of providing SSA and KaSA forward services simultaneously to up to two USATs within the SA antenna beamwidth.

b. **Signal parameters**. TDRS H, I, J spacecraft, in conjunction with the WSC, shall be capable of providing KaSA forward services with signal parameters as specified in Table L-1.

## *TABLE L-1. KaSA Forward Signal Parameters*

| Parameter | Requirement |
|---|---|
| 1. Transmit carrier frequency (F) | Tunable from 22.55 to 23.55 Ghz in ≤ 5.0 Mhz steps(1~~-4~~) |
| 2. USAT received carrier frequency(2~~3~~) | $F_R$ Hz |
| 3. For data rates ≤300 kb/sec | |
| a. Ratio of command channel power to range channel power | +10 dB |
| b. Command channel | |
| (1) PN modulation~~Data modulation(4)~~ | ~~B~~PSK, ±90° |
| (2) PN chip rate(3) ~~Data format(6)~~ | $\frac{31}{1469x96}$ x (F - 8.780 -(K x 0.005))Gchips / sec ~~NRZ~~ |
| (3) Data modulation(4) | Modulo-2 added asynchronously to PN code |
| (4) Data format (5) | |
| (5~~3~~) Data Rate | 1 to 300 kb/sec |
| (6~~4~~) Carrier suppression, minimum | 30 dB |
| (7) PN code length | $2^{10}$ - 1 chips |
| (8) PN code family | Gold code, per STDN No. 108 |
| c. Range channel (6) | |
| (1) PN modulation | PSK, ±90° |
| (2) PN chip rate | Synchronous with the Command Channel PN chip rate ~~≈ 3 Mchips/sec~~ |
| (3) Data modulation | NA |
| (4) Carrier frequency | Command channel carrier frequency delayed 90° |
| (5) Carrier suppression, minimum | 30 dB |
| (6) PN code epoch reference | Epoch (all 1s condition) synchronized to command channel PN code |
| (7) PN code family | Truncated 18-stage shift register sequence per STDN No. 108 |
| 4. For data rates >300 kb/sec | |
| a. Carrier suppression, minimum | 30 dB |
| b. Data modulation | BPSK |
| c. Data format(5) | NRZ |
| d. Data rate | > 300 kb/sec to 25 Mb/sec |

## *TABLE L-1. KaSA Forward Signal Parameters (continued)*

**NOTES:**

1. Data rates and carrier frequencies shall be constrained so that the first null of either the range channel spectrum for data rates ≤ 300 kb/sec, or the spectrum for BPSK modulation for data rates > 300 kb/sec, falls within the 22.550 to 23.550 Ghz range. ~~specified ranges.~~

~~2. (Reserved)~~

2~~3~~. Doppler compensation shall be available for $\dot{R}$ ≤6.7 km/sec for KaSA users. During periods of Doppler compensation, $F_R = F_o \pm E$; where $F_o$ = nominal center frequency of the USAT receiver as defined by the user POCC, and E = 800 X $\ddot{R}$ for $\ddot{R}$ ≤8.3 m/sec$^2$.

3. K is the number of 5 Mhz steps from 22.555 Ghz,. 0 ≤ K ≤ 198, F is the transmit frequency to the USAT in GHz.

4. When forward service data is not received from the POCC, the forward service command channel modulation shall be inhibited.

5. The SN and TDRS H,I, J are transparent to the data format of the forward service data. The particular data format (NRZ-L, NRZ-M, NRZ-S) shall be established in the user POCC.

6. `KaSA service as specified in this document does not support ranging. However, the range channel will be capable of being transmitted for data rates ≤ 300 kb/sec.

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## *TABLE L-2. KaSA Forward Service Signal Distortion Characteristics*

| Parameter | Requirement |
|---|---|
| 1. I/Q power ratio tolerance(1) | ≤ 0.5 dB |
| 21. Modulator phase imbalance, peak (BPSK only) (1) | ±3° |
| 32. Relative phase between command and range channels | 90° ±3° |
| 43. Modulator gain imbalance, peak | ±0.25 dB |
| 54. Data asymmetry, peak | ±3% |
| 65. Data transition time (90% of initial state to 90% of final state) | ≤ 5% of data bit duration but ≥ 4 nsec |
| 76. Phase nonlinearity, peak-to-peak (applies for all types of phase nonlinearities) | ≤ 0.3 rad over ± 17.5 MHz |
| 87. Gain flatness, peak-to-peak | ≤ 1.6 dB over ± 17.5 MHz |
| 98. (Reserved) | |
| 109. AM/AM | > 0 dB/dB |
| 110. AM/PM | ≤ 7° /dB |
| 12. PN code chip jitter, rms (including effects of Doppler compensation) | ≤1° |
| 131. Data bit jitter, peak (2) | ≤ 1% |
| 142. Spurious PM, rms | ≤ 1° |
| 153. Spurious outputs | ≤ -27 dBc |
| 16.4. Frequency stability | |
| a. 1 to 100 sec average time | < 9 x $10^{-13}$ |
| b. 24-hr average time | < 1 x $10^{-12}$ |
| 175. Incidental AM, peak | ≤ 2% |
| 186. Phase noise, rms | |
| a. 1 Hz to 10 Hz | ≤ 2.4° |
| b. 10 Hz to 32 Hz | ≤ 2.5° |
| c. 32 Hz to 1 kHz | ≤ 5.3° |
| d. 1 kHz to 25 MHz | ≤ 2.0° |
| 19. PN code chip skew, peak | ≤ 0.01 chip |
| 20. PN code chip asymmetry, peak | ≤ 0.01 chip |
| 21. PN code chip rate offset, peak (relative to absolute coherence with carrier) | ≤ 0.01 chip/sec |

**NOTES:**

1. For forward service with data rate ≤ 300 kb/sec. this tolerance applies to the ratio of the command channel power to the range channel power:~~Applies to:~~

~~a. Command channel BPSK data modulation for data rates ≤ 300 kb/sec.~~

~~b. BPSK data modulation for data rates>300 kb/sec.~~

2. The total bit jitters is the sum of the weighted spurious and random jitter components.

## *TABLE L-3. KaSA Forward Service Parameters*

| Parameter | Requirement |
|---|---|
| 1. FOV, minimum | |
| a. LEO program track mode | ±10.5° conical |
| b. Program track mode | ±22.5° East-West<br>±31.0° North-South<br>Elliptical |
| c. Autotrack mode(1) | ±22.5° East-West<br>±31.0° North-South<br>Elliptical |
| 2. Angular rate $\dot{\theta}$, maximum(2) | |
| a. LEO program track mode | 0.0122°/sec(3) |
| b Program track mode | 0.0135°/sec(4) |
| C Autotrack mode | 0.0135°/sec(4) |
| 3. Polarization | RHC or LHC, selectable |
| 4. Axial ratio, maximum | 1.5 dB over 3 dB beamwidth |
| 5. Signal EIRP, minimum | |
| a. LEO program track mode (6) | 59.5 dBW |
| b. Program track mode(5) | 56.2 dBW |
| c. Autotrack mode(7) | 63.0 dBW |
| 6. RF channel 3 dB bandwidth, ~~3 dB~~ minimum | 50 MHz |
| 7. C/N at output of TDRS H, I, J spacecraft antenna, minimum | 16 dB |

**NOTES:**

1. Forward service in conjunction with return link autotrack.
2. $\dot{\theta}$ is the maximum angular rate for which service shall be provided. $\dot{\theta} = \sqrt{(\dot{\theta}_x)^2 + (\dot{\theta}_y)^2}$, where $\theta_x$ is the North-South component of the angle between the TDRS H, I, J spacecraft/nadir vector and the TDRS H, I, J spacecraft/USAT vector, and where $\theta_y$ is the East-West component.
3. With USAT ephemeris uncertainty of ±1.5 seconds, uniformly distributed along the USAT orbital track.
4. With USAT ephemeris uncertainty of ±4.5 seconds, uniformly distributed along the USAT orbital track.
5. TDRS open-loop antenna pointing, USAT ephemeris uncertainty of ±4.5 seconds, TDRS SA antenna axial ratio of 3 dB.
6. EIRP in the direction of the USAT with USAT ephemeris uncertainty of ±1.5 seconds, uniformly distributed along the USAT orbital track and allowing for SA antenna axial ratio of 3 dB.
7. EIRP in the direction of the USAT during forward service in conjunction with return link autotrack.

### *TABLE L-5. KaSA Return Service Parameters*

| Parameter | Requirement |
|---|---|
| 1. FOV, minimum | |
| a. LEO program track mode | ±10.5° conical |
| b. Program track mode | ±22.5° East-West<br>±31.0° North-South<br>Elliptical |
| C. Autotrack mode | ±22.5° East-West<br>±31.0° North-South<br>Elliptical |
| 2. Polarization | RHC or LHC, selectable |
| 3. Axial ratio, maximum | 1.0 dB over 3 dB beamwidth |
| 4. RF channel 3 dB bandwidth, ~~3 dB~~ minimum | 225 MHz or 650 MHz, selectable by ground operator command |

d. **USAT signal distortion constraints**. TDRS H, I, J spacecraft, in conjunction with the WSC, shall be capable of providing KaSA return services for USATs transmitting a signal with distortion constraints as specified in Table L-6. Definitions of signal distortion constraints are given in Appendix N.

e. **Service configurations**

(1) Each KaSA return service shall provide relay of two independent data channels or a single data channel.

(2) TDRSS shall be capable of providing KaSA return service for the following DG2 configurations:

(a) Single data channel, BPSK, rate 1/2 coded.

(b) Single data channel, BPSK, uncoded.

(c) Single data channel, balanced SQPSK, rate 1/2 coded alternating coded symbols on I and Q channels, with data rates < 10 Mb/sec.

(d) Single data channel, QPSK or balanced SQPSK, I and Q channel data individually rate 1/2 coded.

(e) Single data channel, balanced SQPSK, alternating I/Q data, uncoded.

(f) Dual data channel, QPSK or SQPSK, rate 1/2 coded.

(g) Dual data channel, QPSK or SQPSK, uncoded.

f. **Coding and interleaving configurations**. TDRSS shall be capable of providing KaSA return services with coding and interleaving configurations as specified for KSA in Appendix K.

## *TABLE L-6. KaSA Return Service USAT Signal Distortion Constraints (continued)*

| Parameter | Requirement |
|---|---|
| 15. Frequency stability, peak | |
| a. 1 sec average time | ≤ $3 \times 10^{-9}$ |
| b. 5 hr average time | ≤ $1 \times 10^{-7}$ |
| c. 48 hr average time | ≤ $3 \times 10^{-7}$ |
| 16. Incidental AM, peak | |
| a. At frequencies > 100 Hz for data rates ≥ 1 kb/sec~~≤ 2 kHz~~ | ≤ 5% |
| b. For autotrack~~At frequencies between 2 kHz and 10 kHz~~ | ≤ 0.6% 10 Hz - 2 kHz<br>≤ 3% 10 Hz - 10 kHz |
| ~~c. At frequencies ≥ 10 kHz~~ | ~~≤ 5%~~ |
| 17. Phase noise, rms | |
| a. 1 Hz to 10 Hz | ≤ 27.2° |
| b. 10 Hz to 100 Hz | ≤ 13.6° |
| c. 100 Hz to 1 kHz | ≤ 3.6° |
| d. 1 kHz to 150 MHz | ≤ 2.0° |
| 18. I/Q symbol skew, peak (relative to requirements for I/Q data synchronization, where appropriate) | ≤ 3% |
| 19. Maximum user EIRP | 75 dBW |
| 20. Axial ratio for autotrack(4) | ≤ 1.0 dB |

**NOTES**:

1. For uncoded data, the symbol parameters should be interpreted as data bit parameters.
2. For the purposes of minimum bandwidth definition, the symbol rate for Biϕ formatted data shall be twice the symbol rate prior to NRZ-to-Biϕ data format conversion.
3. The total symbol jitter is the sum of the weighted spurious and random jitter components. The values apply to rate 1/2 convolutionally encoded data signals.
4. Applies to TDRSS return link only.

(3) Service configurations specified in e, above.

(4) Coding and/or interleaving configurations specified in f, above.

(5) USAT dynamics specified in g, above.

(6) Ephemeris uncertainty specified in h, above.

(7) $P_{rec}$ requirements specified in i, above.

k. **Data transition characteristics**. TDRSS shall be capable of maintaining clock synchronization of a KaSA return signal with data transition characteristics as specified in Appendix K.

l. **Service restriction**. KaSA return service is not required when:

(1) The center of the sun within 0.5 degrees of the TDRS H, I, J spacecraft service providing SA antenna boresight.

(2) The ratio of the desired user received power to composite interference power contained within the channel bandwidth from other users is less than 30 dB ~~for DG2~~.

m. **Antenna autotrack acquisition**. Antenna autotrack acquisition requirements for KaSA shall be as specified ~~for KSA~~ in 5.2.2.3.2.7.a ~~Appendix K~~ with~~: the following exceptions:~~

(1) ~~The~~ USAT dynamics are as specified in g, above.

(2) ~~The~~ USAT ephemeris uncertainty is as specified in h, above.

n. **Signal acquisition**. Signal acquisition requirements for KaSA shall be as specified for KSA in Appendix K with the following exceptions:

(1) The USAT dynamics are as specified in g, above.

(2) The USAT ephemeris uncertainty is as specified in h, above.

o. **Signal tracking performance**. Signal tracking performance for KaSA shall be as specified for KSA in Appendix K with the following exceptions:

(1) The USAT dynamics are as specified in g, above.

(2) The USAT ephemeris uncertainty is as specified in h, above.

p. **Reacquisition performance**. Reacquisition performance for KaSA return service shall be as specified for KSA return service in Appendix K with the exception that the USAT dynamics are as specified in g, above.

## *TABLE K-3. Forward Service Signal Distortion Characteristics*

| Parameter | MA | SSA | KSA |
|---|---|---|---|
| 1. I/Q power ratio tolerance(1) | ≤ 0.5 dB | ≤ 0.5 dB | ≤ 0.5 dB |
| 2. Modulator phase imbalance, peak (BPSK only) | ±3° | ±3° | ±3° |
| 3. Relative phase between command and range channels | 90° ± 3° | 90° ± 3° | 90° ± 3° |
| 4. Modulator gain imbalance, peak | ±0.25 dB | ±0.25 dB | ±0.25 dB |
| 5. Data asymmetry, peak | ±3% | ±3% | ±3% |
| 6. Data transition time (90% of initial state to 90% of final state) | ≤ 5% of data bit duration but ≥ 8 nsec | ≤ 5% of data bit duration but ≥ 8 nsec | ≤ 5% of data bit duration but ≥ 4 nsec |
| 7. Phase nonlinearity, peak-to-peak (applies for all types of phase nonlinearities) | ≤ 0.4 rad over ±2.1 MHz | ≤ 0.3 rad over ±7 MHz | ≤ 0.3 rad over ±17.5 MHz |
| 8. Gain flatness, peak-to-peak | ≤ 1.6 dB over ±2.1 MHz | ≤ 1.6 dB over ±7 MHz | ≤ 1.6 dB over ±17.5 MHz |
| 9. (Reserved) | | | |
| 10. AM/AM | > 0 dB/dB | > 0 dB/dB | > 0 dB/dB |
| 11. AM/PM | ≤ 10°/dB | ≤ 10°/dB | ≤ 7°/dB |
| 12. PN code chip jitter, rms (including effects of Doppler compensation) | ≤ 1° | ≤ 1° | ≤ 1° |
| 13. Data bit jitter, peak(2) | ≤ 1% | ≤ 1% | ≤ 1% |
| 14. Spurious PM, rms | ≤ 1° | ≤ 1° | ≤ 1° |
| 15. Spurious outputs | ≤ -27 dBc | ≤ -27 dBc | ≤ -27 dBc |
| 16. Frequency stability | | | |
| a. 1 to 100 sec average time | $< 9 \times 10^{-13}$ | $< 9 \times 10^{-13}$ | $< 9 \times 10^{-13}$ |
| b. 24-hr average time | $< 1 \times 10^{-12}$ | $< 1 \times 10^{-12}$ | $< 1 \times 10^{-12}$ |
| 17. Incidental AM, peak | ≤ 2% | ≤ 2% | ≤ 2% |
| 18. Phase noise, rms | | | |
| a. 1 Hz to 10 Hz | ≤ 1.5° | ≤ 1.5° | ≤ 1.5° |
| b. 10 Hz to 32 Hz | ≤ 1.5° | ≤ 1.5° | ≤ 1.5° |
| c. 32 Hz to 1 kHz | ≤ 4.0° | ≤ 4.0° | ≤ 4.0° |
| d. 1 kHz to 3 MHz | ≤ 2.0° | NA | NA |
| e. 1 kHz to ~~6~~10 MHz | NA | ≤ 2.0° | NA |
| f. 1 kHz to 25 MHz | NA | NA | ≤ 2.0° |
| 19. PN code chip skew, peak | ≤ 0.01 chip | ≤ 0.01 chip | ≤ 0.01 chip |
| 20. PN code chip asymmetry, peak | ≤ 0.01 chip | ≤ 0.01 chip | ≤ 0.01 chip |
| 21. PN code chip rate offset, peak (relative to absolute coherence with carrier) | ≤ 0.01 chip/sec | ≤ 0.01 chip/sec | ≤ 0.01 chip/sec |

**NOTES**:

1. For forward service with data rate ≤ 300 kb/sec, this tolerance applies to the ratio of the command channel power to the range channel power.

2. The total bit jitter is the sum of the weighted spurious and random jitter components.

### *TABLE K-4. Forward Service Parameters*

| Parameter | MA | SSA | KSA |
|---|---|---|---|
| 1. FOV, minimum | ±13° conical(1) | ±22.5° East-West<br>±31.0° North-South<br>Elliptical | ±22.5° East-West<br>±31.0° North-South<br>Elliptical |
| 2. Angular rate $\dot{\theta}$, maximum(2) | 0.036°/sec | 0.036°/sec | 0.0135°/sec |
| 3. Polarization | LHC | RHC or LHC, selectable | RHC or LHC, selectable |
| 4. Axial ratio, maximum | 1.5 dB over 3-dB formed beamwidth | 1.5 dB over 3-dB beam-width | 1.0 dB over 3-dB beamwidth |
| 5. Signal EIRP, minimum | | | |
| a. Program track mode(3) | 34.0 to 42.0 dBW adjust-able in ≤1.0 dB steps(1,4) | 36.3 to 48.5 dBW(4) adjust-able in ≤ 1.0 dB steps | 39.6 + X dBW(5,6) |
| b. Autotrack mode(6,7) | NA | NA | 39.0 to 49.0 dBW adjustable in ≤ 1.0 dB steps |
| 6. RF channel 3 dB bandwidth, ~~3 dB~~ minimum | 6 MHz | 20 MHz | 50 MHz |
| 7. C/N at output of TDRS H, I, J spacecraft antenna, minimum | 16 dB | 16 dB | 16 dB |

**NOTES*:***

1. For a FOV less than or equal to ±10.5° conical, the minimum EIRP shall be from 34 to 42 dBW adjustable in ≤1.0 dB steps. For a FOV greater than ±10.5° conical, and less than or equal to ±13° conical, the minimum EIRP shall be greater than 34 dBW.

2. $\dot{\theta}$ is the maximum angular rate for which service shall be provided. $\dot{\theta} = \sqrt{(\dot{\theta}_x)^2 + (\dot{\theta}_y)^2}$, where $\theta_x$ is the North-South component of the angle between the TDRS H, I, J spacecraft/nadir vector and the TDRS H, I, J spacecraft/USAT vector, and where $\theta_y$ is the East-West component.

3. EIRP toward USAT with open-loop antenna pointing.

4. With USAT ephemeris uncertainty of ±9 seconds, uniformly distributed along the USAT orbital track.

5. X is the loss in dB arising from a receiving USAT with a 6-dB antenna axial ratio.

6. With USAT ephemeris uncertainty of ±4.5 seconds, uniformly distributed along the USAT orbital track.

7. EIRP in the direction of the USAT during forward service in conjunction with return link autotrack.

### *TABLE K-5. Return Service Signal Parameters (continued)*

**NOTES:**

7. The data format shall be NRZ-L, M, S at the convolutional encoder input when convolutional coding is used.

8. The output of the convolutional encoder may be NRZ-to-Biϕ converted for MA and SSA. The output of the convolutional encoder may be NRZ-to-Biϕ converted for KSA I and Q data rates ≤ 5 Mb/sec. This capability shall not be used with symbol interleaving. No $G_2$ inversion shall occur in the convolutional encoder when NRZ-to-Biϕ conversion is performed.

9. Data signals on I and Q channels may be independent and asynchronous. If the I and Q channel data signals are independent, the sum of the data rates on the I and Q channels shall not exceed the total maximum data rate. For DG2 and for identical symbol rates on the I and Q channels, the I and Q channels will be offset relative to one another by one half symbol period. When Biϕ format conversion is used, the maximum data rates are reduced by a factor of 2. Rate 1/2 or rate 1/3 convolutional encoding is required for S-band return services. For DG1 S-band services, data rate restrictions apply to data prior to rate 1/2 coding; for DG1 mode 3 Q-channel rate 1/3 coding, data rate restrictions are reduced by a factor of 1.5. For KSA services, data rate restrictions apply to uncoded data; for rate 1/2 coding, data rate restrictions are reduced by a factor of 2. Rate 1/3 convolutional encoding is not applicable for KSA services. Biϕ data format will not be used for data rates >5 Mbps.

10. For rate 1/2 coding, the maximum Q channel data rate shall be 75 Mb/sec.

### *TABLE K-6. Return Service Parameters*

| Parameter | MA | SSA | KSA |
|---|---|---|---|
| 1. FOV, minimum | ±13° conical(1) | ±22.5° East-West<br>±31.0° North-South<br>Elliptical | ±22.5° East-West<br>±31.0° North-South<br>Elliptical |
| 2. Polarization | LHC | RHC or LHC, selectable | RHC or LHC, selectable |
| 3. Axial ratio, maximum | 1.5 dB over 3-dB formed beamwidth | 1.5 dB over 3-dB beamwidth | 1.0 dB over 3-dB beamwidth |
| 4. RF channel 3 dB bandwidth, ~~3 dB~~ minimum | 6 MHz | 10 MHz | 225 MHz |

**NOTES:**

1. For a FOV less than or equal to ±10.5° conical, the TDRS H, I, J spacecraft minimum G/T is 4.5 dB/K. For a FOV greater than ±10.5° conical, and less than or equal to ±13° conical, the TDRS H, I, J spacecraft minimum G/T is -1.5 dB/K.

*TABLE K-7. Return Service USAT Signal Distortion Constraints (continued)*

| Parameter | MA | SSA | KSA |
|---|---|---|---|
| 13. Symbol jitter and jitter rate[1,3] | ≤ 0.1% | ≤ 0.1% | ≤ 0.1% |
| 14. Spurious PM, rms | ≤ 2° | ≤ 2° | ≤ 2° |
| 15. Spurious outputs | | | |
| a. Within data bandwidth | ≤ -30 dBc | ≤ -30 dBc | ≤ -30 dBc |
| b. Between data bandwidth and channel bandwidth | ~~≤ -15 dBc~~NA | ~~≤ -15 dBc~~NA | ≤ -15 dBc |
| b1. Between data bandwidth and 2 times channel bandwidth | ≤ -15 dBc | ≤ -15 dBc | NA |
| c. Between channel bandwidth and 2 times channel bandwidth | ~~≤ -15 dBc~~NA | ~~≤ -15 dBc~~NA | ≤ -25 dBc |
| d. Outside of 2 times channel bandwidth | ≤ -30 dBc | ≤ -30 dBc | ≤ -30 dBc |
| 16. Frequency stability, peak | | | |
| a. 1 sec average time | ≤ $3 \times 10^{-9}$ | ≤ $3 \times 10^{-9}$ | ≤ $3 \times 10^{-9}$ |
| b. 5 hr average time | ≤ $1 \times 10^{-7}$ | ≤ $1 \times 10^{-7}$ | ≤ $1 \times 10^{-7}$ |
| c. 48 hr average time | ≤ $3 \times 10^{-7}$ | ≤ $3 \times 10^{-7}$ | ≤ $3 \times 10^{-7}$ |
| 17. Incidental AM, peak | | | |
| a. At frequencies ≥ 10 Hz for data rates < 1 kb/sec and at frequencies > 100 Hz for data rates ≥ 1 kb/sec | ≤ 5% | ≤ 5% | NA |
| b. ~~At frequencies ≤ 2 kHz~~For autotrack | NA | NA | ≤ 0.6% 10 Hz-2 kHz |
| ~~c. At frequencies between 2 kHz and 10 kHz~~ | ~~NA~~ | ~~NA~~ | ≤ 3% 10 Hz – 10 kHz |
| ~~d. At frequencies ≥ 10 kHz~~ | ~~NA~~ | ~~NA~~ | ~~≤ 5%~~ |
| 18. Phase noise, rms | | | |
| a. Coherent turnaround (assumes 0° forward link phase noise) | | | |
| (1) 1 Hz to 10 Hz | ≤ 1.0° | ≤ 1.0° | ≤ 3.0° |
| (2) 10 Hz to 1 kHz | ≤ 1.0° | ≤ 1.0° | ≤ 3.0° |
| (3) 1 kHz to 3 MHz | ≤ 1.0° | NA | NA |
| (4) 1 kHz to 6 MHz | NA | ≤ 1.0° | NA |
| (5) 1 kHz to 150 MHz | NA | NA | ~~≤ 2.0°~~1.0° |

*TABLE K-7. Return Service USAT Signal Distortion Constraints (continued)*

| Parameter | MA | SSA | KSA |
|---|---|---|---|
| b. Non-coherent TCXO (return link not coherently related to forward link) | | | |
| (1) 1 Hz to 10 Hz | ≤ 2.0° | ≤ 2.0° | ≤ 15.0° |
| (2) 10 Hz to 100 Hz | ≤ 1.0° | ≤ 1.0° | ≤ 7.5° |
| (3) 100 Hz to 1 kHz | ≤ 1.0° | ≤ 1.0° | ≤ 2.0° |
| (4) 1 kHz to 3 MHz | ≤ 1.0° | NA | NA |
| (5) 1 kHz to 6 MHz | NA | ≤ 1.0° | NA |
| (6) 1 kHz to 150 MHz | NA | NA | ≤ ~~1~~2.0° |
| c. Non-coherent TCXO with USO (return link not coherently related to forward link) | | | |
| (1) 1 Hz to 10 Hz | ≤ 1.0° | ≤ 1.0° | ≤ 5.9° |
| (2) 10 Hz to 100 Hz | ≤ 1.0° | ≤ 1.0° | ≤ 7.4° |
| (3) 100 Hz to 1 kHz | ≤ 1.0° | ≤ 1.0° | ≤ 2.0° |
| (4) 1 kHz to 3 MHz | ≤ 1.0° | NA | NA |
| (5) 1 kHz to 6 MHz | NA | ≤ 1.0° | NA |
| (6) 1 kHz to 150 MHz | NA | NA | ≤ ~~1~~2.0° |
| 19. I/Q symbol skew, peak (relative to requirements for I/Q data synchronization, where appropriate) | ≤ 3% | ≤ 3% | ≤ 3% |
| 20. I/Q PN code chip skew (relative to 0.50 chip) | ≤ 0.01 chip | ≤ 0.01 chip | ≤ 0.01 chip |
| 21. PN code chip rate offset, peak (relative to absolute coherence with carrier) | ≤ 0.01 chip/sec | ≤ 0.01 chip/sec | ≤ 0.01 chip/sec |
| 22. Maximum user EIRP | 45 dB W | 45 dBW | 60 dBW |
| 23. Axial ratio for autotrack[4] | NA | NA | ≤ 3.0 dB |

**NOTES**:

1. For uncoded data, the symbol parameters should be interpreted as data bit parameters.
2. For the purposes of minimum bandwidth definition, the symbol rate for Biϕ formatted data shall be twice the symbol rate prior to NRZ-to-Biϕ data format conversion.
3. The symbol jitter and jitter rate are defined in Section 5.2.2.3.2.2.l as the user transmitted peak clock frequency jitter and peak clock jitter rate (sinusoidal or 3σ random) as a percent of the symbol clock rate. Jitter and jitter rates greater than 0.1% and less than or equal to 2.0% are applicable to KSHR service only.
4. Applies to TDRSS return link only.

*TABLE K-9. Return Service Data Coding Configurations*

| Data Configuration[1] | | Convolutional Codes[3] | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| **Single data channel** | DG1, mode 1 & 2 | MA, SSA, KSA | NA | NA |
| | DG1, mode 3[2] | MA, SSA, KSA | NA | MA, SSA |
| | DG2 | MA, SSA, KSA | MA, SSA (BPSK only) | MA, SSA |
| **Dual data channel** | DG1, mode 1 & 2 | MA, SSA, KSA | NA | NA |
| | DG1, mode 3 | MA, SSA, KSA | NA | MA, SSA |
| | DG2 | MA, SSA, KSA | NA | MA, SSA |

**NOTES**:

1. For S-band service, interleaving is required for symbol rates > 300 ks/sec as specified in 405-TDRS-RP-SY-001, Appendix D.
2. DG1 mode 3 may provide a single data channel on the Q channel and the range PN code on the I channel without data modulation on the I channel.
3. Convolutional codes are as specified in K.1.3.2.f.

(7) For S-band service at symbol rates > 300 ks/sec, symbol interleaving shall be used as specified in 405-TDRS-RP-SY-001, Appendix D.

g. **USAT dynamics**

(1) TDRSS shall be capable of providing return services to USATs with dynamics as specified in Table K-10.

*TABLE K-10. USAT Dynamics*

| Parameter[1] | Free Flight | Powered Flight[2] | |
|---|---|---|---|
| | | Non-Shuttle[3] | Shuttle[2] |
| $\dot{R}$ | ≤ 12 km/sec | ≤ 15 km/sec | ≤ 12 km/sec |
| $\ddot{R}$ | ≤ 15 m/sec$^2$ | ≤ 50 m/sec$^2$ | ≤ 50 m/sec$^2$ |
| $\dddot{R}$ | ≤ 0.02 m/sec$^3$ | ≤ 2 m/sec$^3$ | ≤ 2 m/sec$^3$ |

**NOTES**:

1. R is the USAT-to-TDRS H, I, J spacecraft range.
2. Supported by SSA only.
3. Supported by SSA and MA.

(2) In addition, TDRSS shall be capable of providing program track return service to S-band USATs with a maximum angular rate of 0.036°/sec.

# Appendix M. White Sands Complex Ground Terminal Requirements

## M.1 Scope

### M.1.1 *General*

This appendix specifies the requirements governing all changes to the White Sands Complex (WSC) necessary to accommodate TDRS H, I, J requirements for spacecraft operations and support of user services.

These changes will include, but are not necessarily limited to: provisions for accommodation of spacecraft collocation; changes associated with TDRS H, I, J MA forward and return services; and provisions to accommodate TDRS H, I, J Ka-band user services.

Necessary WSC changes as identified above shall not have adverse impact on WSC support of the existing on-orbit TDRS spacecraft for health and safety and user services.

### M.1.2 *WSC configuration identification*

a. The White Sands Complex (WSC) Ground Terminals (GTs) include: the Danzante ground terminal and Cacique ground terminal. The existing GT architecture and interfaces are illustrated in Figure M-1. The Danzante and Cacique hardware and software configurations are defined in 504-TDRS-HIJ-SY-03.

b. Each GT includes three independent Space-Ground Link Terminals (SGLTs) which will support TDRSS user telecommunications, tracking and End-to-End Test (EET) services, and TDRS Tracking, Telemetry and Command (TT&C) functions. Two of the three SGLTs in each GT will support TDRSS user telecommunications, tracking and EET services as defined in Appendix K (with the exception of autotrack acquisition requirements, which are given in 5.2.2.3.2.7.a instead of Appendix K) via a TDRS H, I, J spacecraft and TDRS H, I, J spacecraft TT&C functions.

**M.1.3** ***Restrictions on changes to WSC configuration items***. If changes are required to any element of the NASA Space Network other than the GT, the contractor shall identify these changes in sufficient detail to permit NASA assessment of cost, schedule and technical risk of implementation.

(3) One KSA EET service as specified in Appendix K for a single assigned TDRS H, I, J spacecraft, as applicable.

e. Each SGLT, in conjunction with an assigned TDRS H, I, J spacecraft, shall meet the KaSA service requirements specified in Appendix L.2.

f. Each GT shall be capable of supporting two TDRS H, I, J spacecraft providing MA, SSA, KSA, and KaSA user services.

g. Contractor modifications in support of KaSA service shall not degrade the performance of the WSC as given in this specification when supporting TDRS F1 - F7 spacecraft.

h. Each GT, in support of KaSA user services, shall meet the requirements in Sections M.2.4 through M.2.9, M.2.10.1, M.2.10.2, and M.2.11 through M.2.14.

i. Availability requirements

(1) The inherent availability requirements for KaSA shall be as specified for SA services in Section 13.3, "Inherent Availability."

(2) The operational availability requirements for KaSA shall be as specified for KSA in Section 13.4, "Operational Availability."

## M.3.2 *KaSA SGLT requirements*

### M.3.2.1 *KaSA forward service equipment requirements*

a. Each SGLT shall include two independent sets of KSAF equipment (designated KSA-1 and KSA-2).

b. Each set of KSAF equipment shall include two identical service chains for redundancy.

c. Each KSAF service chain shall be capable of supporting a KSAF user service and a KaSAF user service, but not simultaneously.

d. For KaSAF service support via a TDRS H, I, J spacecraft, the KSAF service chains shall meet the KSA functional requirements specified in Section 5.2.1.2.3, "KSAF Equipment," except:

(1) Shuttle service support requirements are not applicable.

(2) Command channel PN coding requirements are not applicable.

(3) EET service support requirements are not applicable.

e. The KaSAF service support via a TDRS H, I, J spacecraft, the KSAF service chains shall meet the KSA performance requirements specified in Section 5.2.1.3.2, "KSAF Equipment," except:

(1) The carrier signal will be modulated as specified in Appendix ~~K~~L, Table ~~K-2~~L-1.